

CLAIMS

What is claimed is:

- 1 1. For a wavelength division multiplexed optical network having a plurality of
2 optical nodes coupled by spans with each optical node capable of receiving at least one
3 optical pre-amplifier for each input fiber and at least one optical post-amplifier for each
4 output fiber, a computer implemented method of selecting amplifier placement, the
5 method comprising:
6 selecting an optical power criterion for constraining placement of one or more
7 optical amplifiers in the optical network, the optical power criterion being indicative of a
8 sufficient minimum received power in at least one receiver;
9 placing at least one amplifier in accord with the optical power criterion to
10 form an initial placement of amplifiers; and
11 determining a set of amplifier placement configurations which are consistent
12 with the initial placement of amplifiers.
1 2. The method of claim 1, wherein the optical power criterion comprises:
2 placing an amplifier in a pre-selected node location responsive to an optical loss
3 associated with at least one portion of a lightpath of the network exceeding a threshold
4 loss.
1 3. The method of claim 1, wherein the optical criterion comprises:
2 analyzing the power level of at least one wavelength channel from a source node
3 and placing an amplifier at a node location prior to a first node location in which the
4 power level decreases below a threshold power level.
1 4. The method of claim 1, wherein the optical power criterion comprises:
2 calculating an aggregate loss for all of the spans and all of the nodes; and

3 forming a constraint on the number of amplifier required in the optical network by
4 determining an aggregate number of amplifiers required for the aggregate optical loss.

1 5. The method of claim 1, further comprising:

2 performing a quality of service analysis upon each of the amplifier placement
3 configurations; and

4 selecting the amplifier placement configuration having a desired level of
5 service and a minimum number of optical amplifiers.

1 6. An optical network designed by the method of claim 5.

1 7. An optical network designed by the method of claim 1.

1 8. For a wavelength division multiplexed optical network having a plurality of
2 optical nodes coupled by spans with each optical node capable of receiving at least one
3 optical pre-amplifier for each input fiber and at least one optical post-amplifier for each
4 output fiber, a computer implemented method of selecting amplifier placement, the
5 method comprising:

6 selecting a plurality of light paths of the optical network;

7 for each selected light path, placing optical amplifiers in node locations

8 requiring optical amplification to form an initial placement of amplifiers; and

9 determining a set of amplifier placement configurations which are consistent
10 with the initial placement of amplifiers.

1 9. The method of claim 8, wherein an optical amplifier is placed in a node
2 location responsive to an optical loss associated with at least one portion of the lightpath
3 exceeding a threshold loss.

1 10. The method of claim 8, further comprising:

2 analyzing the power level of at least one wavelength channel from a source node
3 and placing an amplifier at a node location prior to a first node location in which the
4 power level decreases below a threshold power level.

1 11. The method of claim 8, further comprising:
2 calculating an aggregate loss for all of the spans and all of the nodes; and
3 forming a constraint on the number of amplifiers required in the optical network
4 by determining an aggregate number of amplifiers required for the aggregate optical loss.

1 12. The method of claim 8, further comprising:
2 performing a quality of service analysis upon each of the amplifier placement
3 configurations; and
4 selecting the amplifier placement configuration having a desired level of
5 service and a minimum number of optical amplifiers.

1 13. An optical network designed by the method of claim 12.

1 14. An optical network designed by the method of claim 8.

1 15. A computer implemented method for designing a wavelength division
2 multiplexed optical network, the method comprising:
3 providing an interface for a user to input an arrangement of optical nodes
4 coupled by optical fiber spans, each of the optical fiber spans having an associated optical
5 fiber loss that is dependent upon its length and upon an attenuation characteristic of the
6 span;

7 each node having a minimum and a maximum number of possible optical pre-
8 amplifiers which may be coupled to each of its input ports and a minimum and a
9 maximum number of possible optical post-amplifiers which may be coupled to each of its

10 output ports, the optical network having an associated multiplicity of possible optical
11 amplifier placement configurations;
12 for each node of the optical network, configuring optical components of
13 optical add/drop multiplexers to add, drop, and pass through optical wavelength channels
14 according to a channel map for providing services in the optical network, the optical
15 components of the node having an associated optical loss characteristic;
16 selecting a set of optical amplifier placement configurations;
17 analyzing quality of service for each optical amplifier placement configuration
18 in the set of optical amplifier placement configurations; and
19 selecting an optical amplifier placement configuration having a minimum
20 number of optical amplifiers and a desired quality of service.

1 16. The method of claim 15, wherein selecting the set comprises:

2 selecting an optical power criterion for constraining placement of one or more
3 optical amplifiers in the optical network, the optical power criterion being indicative of a
4 sufficient minimum received power in at least one receiver;

5 placing at least one amplifier in accord with the optical power criterion to
6 form an initial placement of amplifiers; and

7 determining a set of amplifier placement configurations which are consistent
8 with the initial placement of amplifiers.

1 17. The method of claim 15, wherein selecting the set comprises:

2 for a node having at least one channel passing through the node, determining a
3 pass-through optical loss associated with the at least one channel passing through the
4 optical node;

5 responsive to the pass-through optical loss exceeding a threshold loss, placing
6 at least one amplifier in the node.

1 18. The method of claim 15, wherein selecting the set comprises:

2 for at least one optical wavelength channel, forming an equivalent optical
3 circuit model having an associated equivalent optical loss to couple a wavelength channel
4 from a first node to a second node in the network; and

5 responsive to the equivalent optical loss exceeding a threshold optical loss,
6 placing an optical amplifier in at least one of the nodes.

1 19. The method of claim 18, wherein the first and second nodes comprise an

2 optical add/drop path, the minimum equivalent loss includes the losses along the
3 add/drop path, and the optical amplifier is placed in one of the nodes along the add/drop
4 path.

1 20. The method of claim 15, wherein selecting the set comprises:

2 for at least one optical wavelength channel that is added and dropped,
3 sequentially moving from an add node to each subsequent node along an optical path to a
4 drop node;

5 at each node in the sequence of nodes along the optical path, determining if an
6 optical amplifier is required to couple the optical wavelength signal to a subsequent node;
7 and

8 responsive to determining that an optical amplifier is required to couple the
9 optical wavelength channel to a subsequent node, placing an amplifier in a node location
10 selected to couple the optical wavelength signal to the subsequent node.

1 21. The method of claim 20, further comprising:

2 performing a power analysis of the wavelength channel along the optical path
3 for an initial optical amplifier configuration; and
4 responsive to the wavelength channel having a power level below a threshold
5 power level in a node, placing an optical amplifier in a previous node.

1 22. The method of claim 15, wherein selecting the set comprises:

2 placing amplifiers proximate high loss regions of the optical network.

1 23. The method of claim 15, wherein selecting the set further comprises:

2 eliminating from consideration amplifier configurations belonging to branches of a
3 decision tree likely to have unacceptably low power for at least one wavelength channel
4 in at least one node.

1 24. The method of claim 15, where selecting the set comprises:

2 placing an optical amplifier in a node, responsive to the optical loss of the node
3 for at least one pass-through channel exceeding a first threshold loss; and

4 placing at least one amplifier proximate one end of a span responsive to
5 determining a path loss for a wavelength channel added in a first node traveling along an
6 optical path including the span to a second node exceeding a second threshold loss.

1 25. The method of claim 24, further comprising:

2 forming configurations having at least one additional optical amplifier.

1 26. The method of claim 15, wherein selecting the set further comprises:

2 calculating an aggregate optical loss for all of the spans and all of the nodes; and

3 forming an estimate of the number of amplifiers required in the optical network
4 by determining an aggregate number of amplifiers required for the aggregate optical loss.

1 27. An optical network designed by the method of claim 15.

1 28. A network design tool for a wavelength division multiplexed optical network
2 in which each optical node is capable of receiving a plurality of optical amplifiers,
3 comprising:
4 selection means for placing at least one optical amplifier to form an initial
5 placement of amplifiers in accord with an optical power criteria;
6 means for forming a set of optical amplifier placement configurations in accord
7 with the initial placement of the selection means; and
8 quality of service means to analyze the quality of service of each amplifier
9 placement configuration.

1 29. A network design tool, comprising:
2 a network configuration module for configuring optical components of nodes
3 of an optical network to add, drop, and pass-through wavelength channels according to a
4 channel map;
5 an amplifier placement selection module for selecting a subset of amplifier
6 placement configurations from the set of all possible amplifier placement configurations;
7 and
8 a quality of service analysis module configured to analyze the quality of
9 service for each amplifier configuration of the subset of amplifier placement
10 configurations and select an amplifier configuration having a minimum number of
11 amplifiers and a desired quality of service.

1 30. The system of claim 29, wherein the amplifier placement selection module
2 places amplifiers proximate high loss regions of the optical network

1 31. The system of claim 29, wherein the amplifier placement selection module
2 eliminates from consideration amplifier configurations belonging to branches of a

3 decision tree likely to have unacceptably low power for at least one wavelength channel
4 in at least one node.

1 32. A wavelength division multiplexed optical network, comprising:
2 at least four optical nodes coupled by fiber optic spans,
3 each node having an optical add/drop multiplexer and each node capable of
4 receiving at least one optical pre-amplifier for each input fiber and at least one optical
5 post amplifier for each output fiber;
6 at least one optical amplifier disposed in the nodes, wherein the configuration
7 of the at least one optical amplifier is selected and validated by a design tool.

8 33. The network of claim 32, wherein the network provides OC-192 compliant
9 services.

1 34. The network of claim 32, wherein the network has at least five nodes.

1 35. The optical network of claim 32, wherein the design tool performs the steps
2 of:
3 selecting a subset of optical amplifier placement configurations;
4 analyzing quality of service for each optical amplifier placement configuration
5 in the subset of optical amplifier placement configurations; and
6 selecting an optical amplifier placement configuration having a minimum
7 number of optical amplifiers and a desired quality of service.